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(71) Applicant(s)
Zafer Mumittin Ure
6 Bevan Close, WARMINGTON,
East Northants, PE8 6WJ, United Kingdom

(72) Inventor(s)
Zafer Mumittin Ure

(74) Agent and/or Address for Service
EPS Ltd
Unit 32, Mere View Industrial Estate,
YAXLEY, Cambs, PE7 3HS,
United Kingdom

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(56) Documents Cited
GB 2365955 A GB 2318180 A
GB 2234339 A GB 1504385 A
GB 0901024 A GB 0900949 A

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(54) Abstract Title
Air cooling unit

(57) An air cooling unit comprises a heat exchanger 19, preferably in the form of a condenser, positioned to be cooled by an air stream 34, with a water spray 32 located on the upstream side of the heat exchanger to direct water onto a single or multi-layered mesh surface 29 also positioned on the upstream side of the heat exchanger. The mesh surface is preferably of wire. Water is then able to evaporate from the mesh so cooling the air stream. The unit may be operated intermittently, eg in peak periods, either by using a sensor measuring ambient temperature, or by using a pressure sensor measuring the pressure of refrigerant in the condenser. The mesh can be metallic or non-metallic, and can be positioned in the unit either using a bracket, frame or clip-on assembly. The wire meshes can be coarse 30 or fine 31, either of diamond or square pattern. By its positioning, the mesh can act as a filter for leaves or dust.

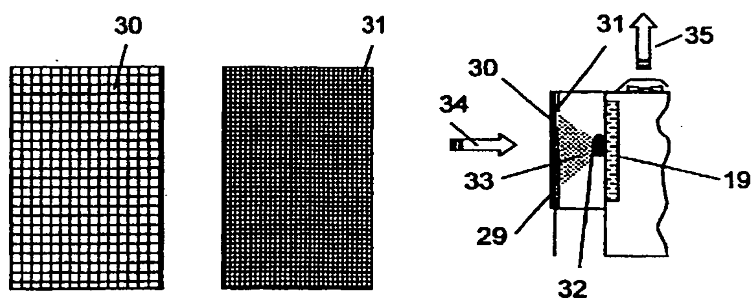

Fig 4

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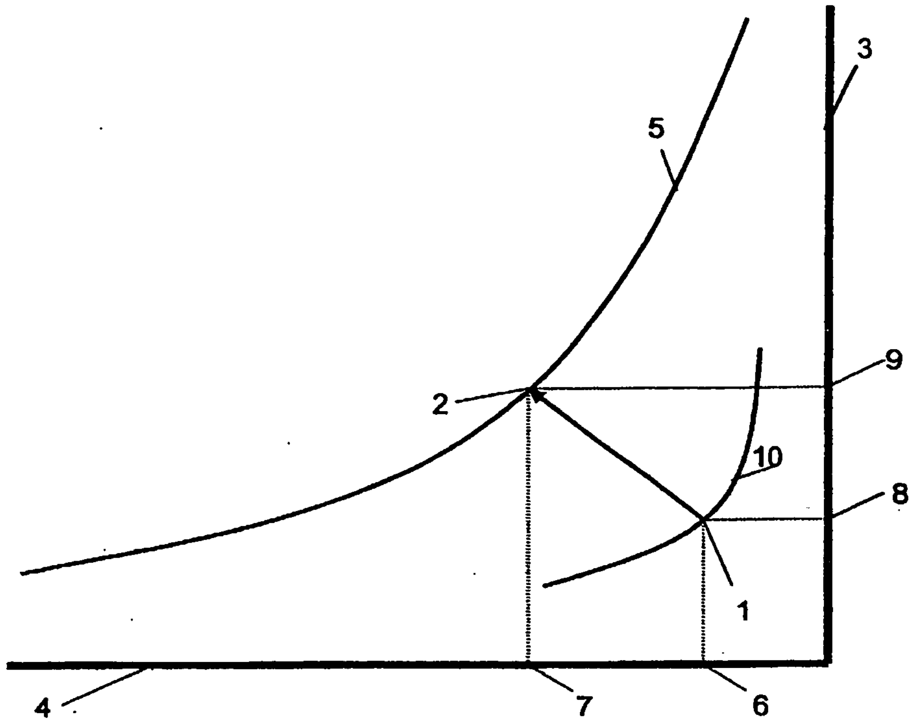

Fig 1

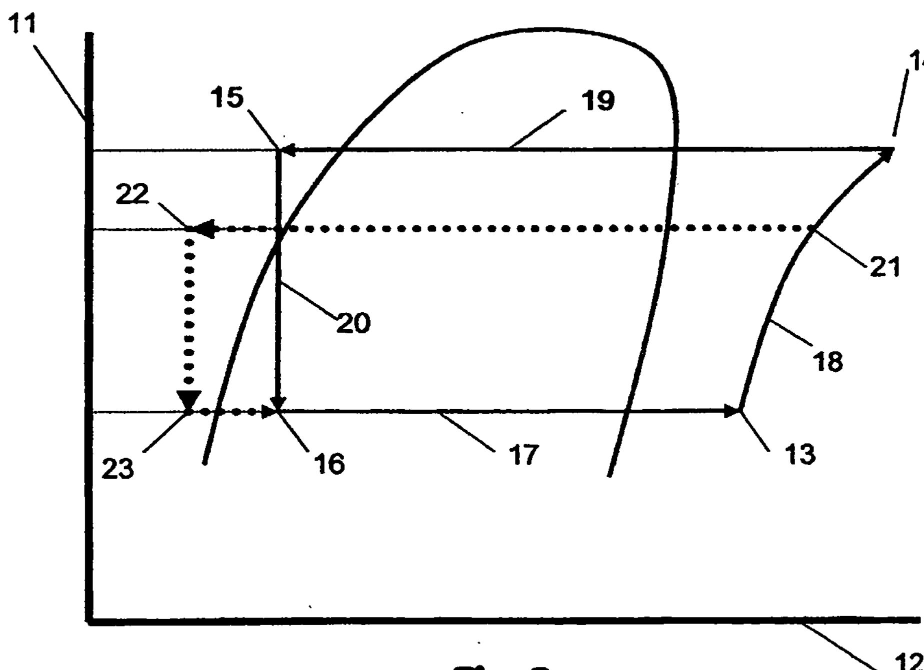

Fig 2

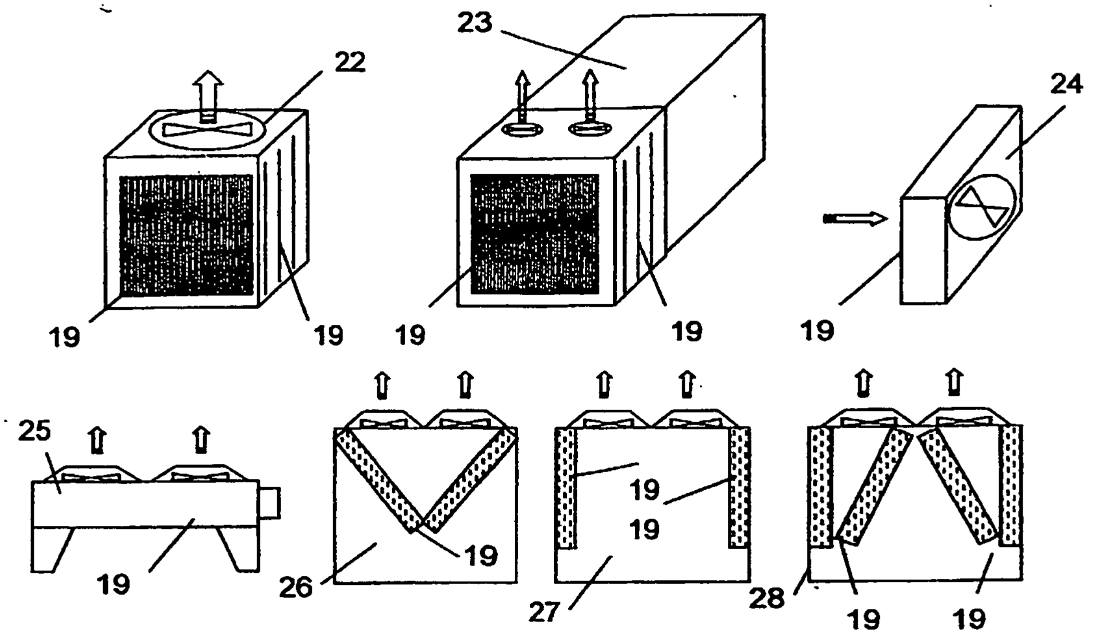

Fig 3

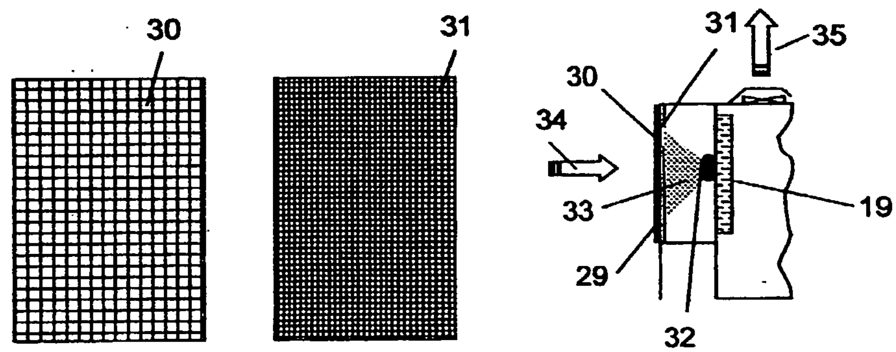

Fig 4

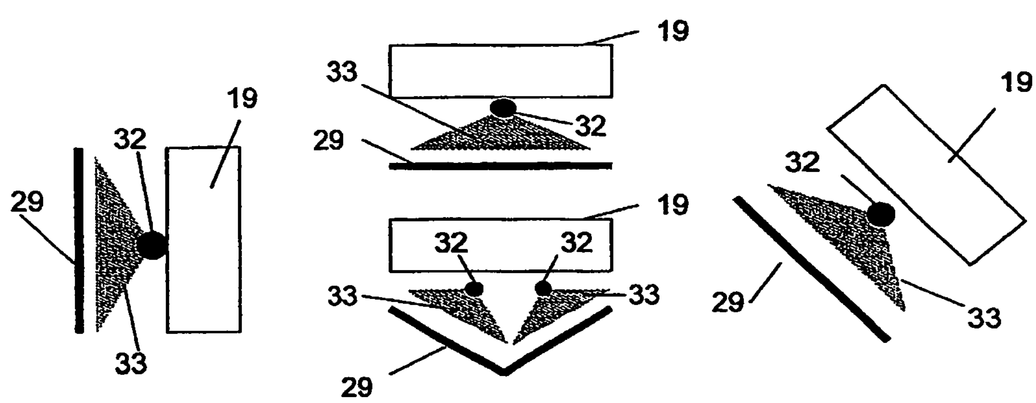

Fig 5

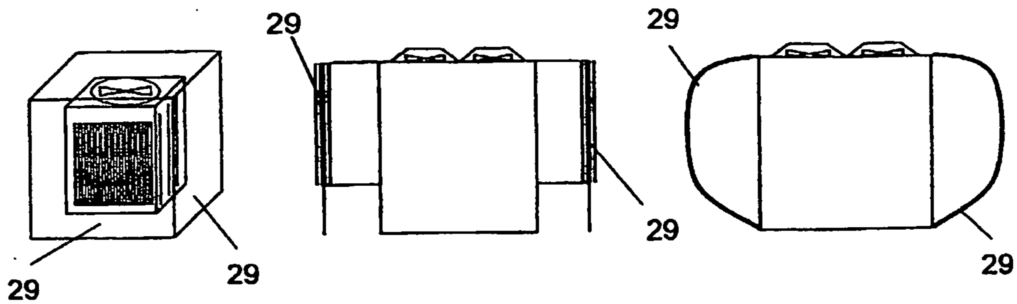

Fig 6

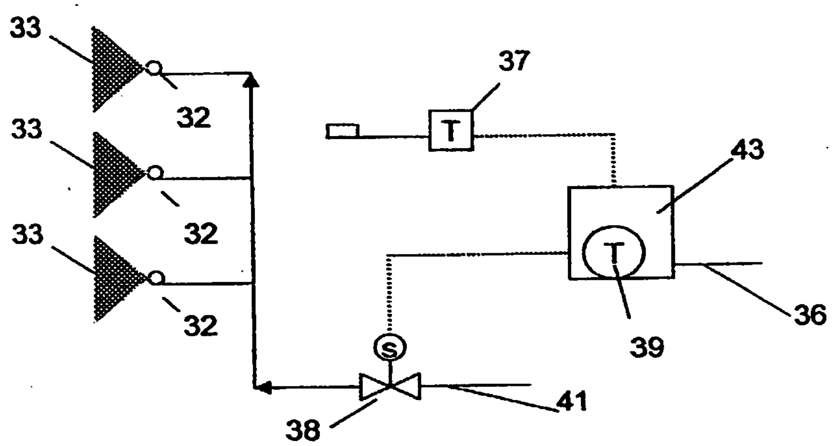

Fig 7

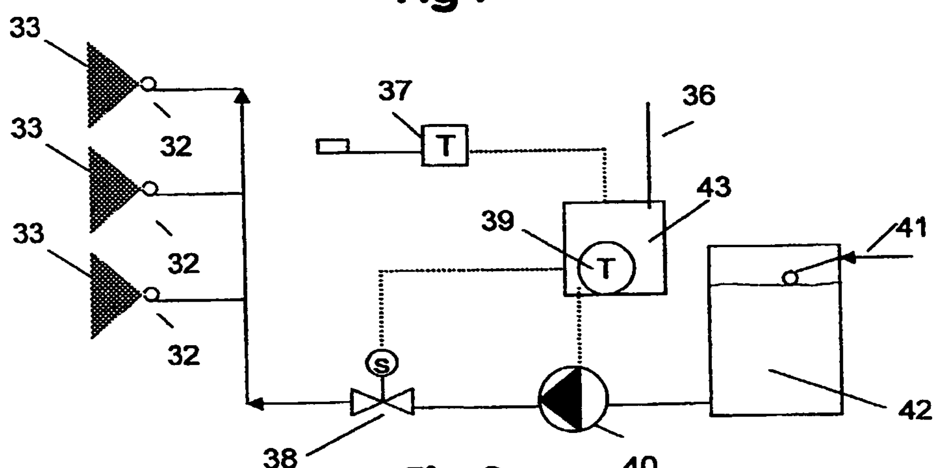

Fig 8

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ADIABATIC AIR COOLING UNIT

The present invention relates to an adiabatic air cooling unit which can be applied for dry heat rejection equipment such as air cooled condenser, dry coolers, air cooled condensing units and air cooled water / process chiller systems incorporating such a module or apparatus.

A conventional air cooled heat rejection system such as air cooled condensers and dry coolers relies on dry bulb temperature of the air which is generally between 5 and 15 °C higher depending on location around the world than the wet bulb temperatures. Traditionally, large heat rejection systems use cooling tower or evaporative coolers in order to reduce the heat rejection equipment size as well as the overall energy consumption due to lower condensing temperatures.

It will readily be apparent to those skilled in the art that between various other heat rejection systems, a wet bulb temperature based heat rejection systems such as evaporative coolers and cooling towers are the most efficient way of handling refrigeration related heat rejection. However, the water based corrosion, maintenance and health problems such as legionella disease moved the industry towards dry bulb heat rejection systems such as air cooled condensers and dry coolers.

However, the wet bulb efficiency advantage is only applicable during peak periods such as high ambient and high load operation conditions but these systems are designed to operate all year round and the wet system still has to be maintained even during low ambient periods, hence, the cost of water maintenance as well as water consumption increases unnecessarily.

This disadvantage can be overcome by eliminating the need for all year round wet operation by means of introducing wet bulb temperature during only peak periods. This operation can be either initiated via ambient sensor or alternatively refrigeration head pressure i.e. condensing pressure limit. As soon as the ambient dry bulb or alternatively the condensing pressure or the combination of both exceeds a pre-set level an adiabatic i.e. air cooling by water evaporation process can be initiated in order to lower the air on temperatures for the condenser, hence, the condensing pressure can be reduced to save energy during peak periods.

This operation not only saves energy but the water consumption of the system can also be reduced considerable. Moreover, the water is used whenever is required at a significantly reduced quantities.

Munter Ltd, UK offers an adiabatic air cooler which consists of a plastic drift eliminator in order to provide surface for water evaporation, water reservoir, pump and associated circulation and spray nozzles. Munter unit is positioned in front of a heat rejection equipment with a large by-pass areas which reduces the overall efficiency of the air stream cooling, the water reservoir contains permanent water which is considered as a health hazard, drift eliminators cause considerable pressure drop and prune to clogging, constant water circulation unnecessarily increases the water consumption and the pump requirement result in energy consumption and regular maintenance requirement.

Van Spall Associates Ltd. offers an atomised nozzles spray system in front of the heat rejection equipment using high pressure nozzles. This system requires high pressure pump complete with water tank and the combination of stagnant water and very fine mist water spray creates ideal conditions for the legionella risk. At high humidity conditions excessive fine mist can not be evaporated and the excessive water mist might be carried over by the fans into to air. The power consumption of the high pressure pump takes some of the efficiency improvements away and it creates additional maintenance issues.

The present invention uses wired mesh apparatus in front of the heat rejection surface to cool the air stream. Wired mesh design reduces the air side pressure drop significantly, hence, effective air flow. Water rapidly and efficiently evaporates on large mesh surface and the present invention use water directly from the main / tap without any water reservoir, hence, the health risk associated with a still water reservoir as well as the water losses due free water evaporation form the surface of the water tank are completely eliminated.

It is vital to keep the heat rejection surface dry during adiabatic spray. Otherwise, the scaling and corrosion due to water impurities will damage and block the heat rejection coils very quickly. The present invention sprays the tap water through nozzles against the air stream towards the mesh and therefore the heat rejection surface remains dry and the adiabatic cooling is achieved using mesh surface area.

Mesh in front of the heat rejection area also acts like a self-cleaning filter and solid materials such as leaves, dust, sand etc. can initially bounce back due to soft surface of the mesh and materials left on the mesh shall be removed via water spray and gravity takes it impact to bring the heavy materials on to the ground.

The present invention makes this technology as a self installed commercial kit which can be bought over the counter and fitted by the end-users. It requires no technical skill and a simple installation instruction should be sufficient to satisfy the public expectation. Hence, the commercial possibility and the way to market of the final product are very encouraging.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 illustrates a Psychometric chart for air system operation.

Figure 2 illustrates a refrigeration cycle Pressure-Enthalpy diagramme.

Figure 3 covers the most commonly used heat rejection systems.

Figure 4 is an embodiment of an adiabatic air cooler unit for heat rejection circuit in accordance with the invention.

Figure 5 is an embodiment of an air cooler unit application in accordance with the invention.

Figure 6 is an embodiment of an air cooler unit general layout in accordance with the invention.

Figure 7 is an embodiment of an air cooler unit water circuit and associated control circuit arrangement for direct main water intake operation in accordance with the invention.

Figure 8 is an embodiment of an air cooler unit water circuit and associated control circuit arrangement for indirect main water intake operation in accordance with the invention.

A typical adiabatic cooling process is illustrated in Figure 1 in the form of a psychometric chart operation. Ambient air 1 is defined by fixed parameters of dry bulb temperature 6, relative humidity 10, moisture content 8 and wet bulb temperature of 2. If water is introduced into an air stream it evaporates and the hidden energy in the form of water evaporation which is in the region of 2500 kJ/kg for an average ambient air operation moves the ambient dry bulb 1 towards the wet bulb temperature line 2 and the efficiency of the evaporation dictates where the final temperature ends. Upstream ambient temperature 1 ends up at a cooler down stream air temperature 7 with high humidity 5 and high moisture content 9. This cooling impact could be as much as 28 °C hot dry places like in the Middle East.

The heat rejection circuit on the down stream receives colder air in comparison with the incoming ambient air. Heat rejection surface area is defined by the configuration of the coil and it is fixed for a given machine, hence, the cold air provided by the additional adiabatic mesh spray increases the heat rejection equipment efficiency due to higher logarithmic mean temperature difference (LMTD). As a results of this efficiency increase the condensing temperature of the refrigerant in the case of direct refrigeration or alternatively the fluid return temperature as in the case of a dry cooler operation decreases. This lower return temperatures from the heat rejection system result in reduced condensing pressures as illustrated in Figure 2.

Low pressure super-heated gas 13 is compressed by the compressor 18 to high pressure high temperature gas 14 which is condensed by a heat rejection equipment 19 to a high pressure liquid form 15. Later this high pressure liquid refrigerant is expanded via an expansion device 20 to provide a low pressure but cold liquid and gas mixture 16. The evaporation of the refrigerant 17 within the cooler circuit provides the cooling effect for the process / fluid. The pressure 11 and enthalpy 12 lines indicate a conventional envelop of a refrigeration cycle but if the present invention is applied the solid line envelop between lines 13-14-15-16-13 becomes a smaller dotted line envelop of 13-21-22-23-13 which has a lower condensing pressure in comparison with solid lines in Figure 2.

The electric energy consumption of a refrigeration compressor 19 heavily depends on the pressure difference between the suction 17 and discharge 19 side of the system and the reduction in condensing pressure with a fixed evaporation pressure results in significant reduction in compressor power consumption. Furthermore, the present invention also provides additional liquid sub-cooling as indicated lines between 15 and 22 provides further energy savings. It is estimated that the overall energy saving could be increased as much as 35% of a conventional dry heat rejection system.

Figure 3 illustrates the most commonly used heat rejection systems in industry. The air side heat rejection surface generally in the form of finned tube heat exchanger and it can be applied either on vertical / horizontal or alternatively "W" / "V" format inclined arrangement. The tube side of the air heat exchanger 19 receives either refrigerant directly or alternatively a heat transfer fluid generally water or water/freeze depressant mixture indirectly from a water cooled heat rejection condenser. Typical arrangement and applications are rectangular air cooled condenser / condensing unit 22, rooftop packaged air handling unit complete with air cooled refrigeration machinery 23, mini-split unit 24, air cooled dry coolers and/or condensers 25 in horizontal or vertical or any other inclined position, air cooled chillers 26,27,29 in various horizontal or vertical , "W" or "V" coil configuration formats.

The present invention is based on a water sprayed mesh 29 apparatus which is fitted into the air stream in front of the heat rejection exchanger 19 as illustrated in Figure 4. Water sprayed meshes 29 can be made in Metallic or Non-metallic such as Nylon, Polyester, Polypropylene, ETFE, woven, non-woven, felts metal or cloths and this mesh apparatus can be fitted either horizontal or vertical or any inclined position in front of a heat rejection exchanger 19 as illustrated in Figure 5.

The fixing of these meshes can be either applied directly on the heat rejection unit, bracketed or alternatively using a custom-made box or frame arrangements as illustrated in Figure 6. This special box or frame allow the air stream to pass through for the heat rejection exchanger while holding the mesh in position and the water is directly sprayed onto the mesh side of the panels against the air stream in order to utilise the adiabatic cooling effect of the water to cool the incoming air stream while keeping the heat exchanger surface dry.

This simple retrofit apparatus of the invention is illustrated in Figure 6. The majority of air cooled heat rejection equipment is based on a tube with extended fin element arrangement 19 and the actual tests indicated that an optimum distance of 500 mm away from the heat rejection surface to achieve the best efficiency of mesh spray application using tap water.

Custom-made coarse meshes 30, 1 cm ~ 10 cm either diamond or square pattern to and fine meshes 31, 0.1mm ~ 10 mm either diamond or square pattern are specially extruded and / or woven for this specific application to stand the extreme outdoor temperature, weather and sun ray conditions. These two different meshes loosely or fully bonded together by means of using thermo-welding, sewing, glue or framework to form a single mesh panel 29 as illustrated in Figure 4. Wired meshes 29 are manufactured in various dimensions and applied either in sectional or linear formats in order to cover the whole face area of the heat rejection surface 19. It is established that the most economical and practical way to cover commercially marketed heat rejection equipment is to produce sectional wired mesh units 29 in 1,000 mm or 1,200mm wide panel sections to match the length of the coil blocks. However, any special , dimension, shape or area can be covered by using different aspect ratios of the wired mesh unit 29.

Wired meshes can be applied either in a single or alternatively multi-layer format in order to match the air flow and surface area requirement for an optimum evaporation efficiency.

Adiabatic cooling affect is provided via either intermittent or alternatively continues water flow / spray 33 over the single or multi-layer wired mesh 29 surface. Water spray / flow headers 32 can be arranged either in horizontal or vertical or alternatively in any inclined pattern to suit the mesh layout in order to cover mesh 29 area.

Figure 7 and Figure 8 illustrate custom-made control panels in order to control the water spray operation. An ambient sensor 37 initiates the water flow/spray operation or alternatively, a condensing pressure switch can also be used either in lieu of ambient sensor 37 or as an over-ride input to overcome high head pressure operation. As in the case of dry cooler application additional external system manual or automatic input and /or the combination of above switches applied in parallel. As soon as the spray/flow request is received an inline solenoid valve 38 is initiated to pass the water flow to satisfy the adiabatic cooling process and the control over this flow/spray operation is provided either within the differential setting of ambient sensor 37 or alternatively manual over-ride, condensing unit head pressure controller i.e. condenser pressure switch or alternatively via the dry cooler fluid return temperature or the combination of all of the above apparatus. Either a simple mechanical cycle timer or PLC based software driven controller 43 terminates the water flow/spray operation in order to enhance the adiabatic cooling effect and reduce water consumption.

If the main water 41 pressure is 1.5 Barg and above Figure 7 concept can be applied to satisfy the adiabatic cooling operation. If the main pressure is less than the required pressure level or due to no running water near by for the flow/spray operation a pressurisation pump set 40 and associated local water reservoir 42 complete with a float valve can be used. The main water flow is filtered by an inline filter to protect the continues water flow operation. As an optional item a water softener can be fitted as part of the proposed control panel.

Small scale units are constructed using 1000 mm (W) and 1200 mm (W) mesh panels 29 complete with frames to suit a number of coil configurations covered in Figure 3. The internal supporting rods and clipping apparatus are manufactured using non-metallic plastic rods, washers, nuts supplied by Bluemay Ltd.,UK complete with 3mm thick Aluminium Bars supplied by Alco, UK or Plastic Bars supplied by KMP Ltd. UK to manufacture support apparatus.

The water flow / spray system 32 is supplied by Lurmark, UK and John Guest Ltd. UK. A number small control panels are built in house complete with all the necessary electrical and control units including timer control 39, main power supply 36, solenoid valve 38, strainer, main water intake 41 and an ambient thermostat / sensor 37. Both electro-mechanical fix cycling timer and PLC software driven controllers which follows the ambient profile to alter the spray duration and frequency with or without pressure set are tested.

The test rig performed well and achieved the design criteria set for a small domestic air cooled condensing unit and it is estimated that the present invention provides almost 30% COP improvement for a peak ambient condition of 40 °C @ 30%RH. The same

operation parameters can be either scaled down or up to match any a large or small heat rejection application for domestic, commercial and industrial applications.

The energy saving is self evident due to lower condensing pressure but it is also important to minimise the water consumption. Hence, the present invention provides a significant water consumption savings in the region of 75% in comparison with other adiabatic cooling unit such as cooling tower and evaporative cooling units available on the market.

The present invention is relatively cost effective to manufacture and the final end-user cost and pay-back times are very attractive due to significant energy savings which can be considered as a self financing product.

The present invention can be applied to both new and retrofit applications for any make and model on the market.

Furthermore, the present invention can be considered as a DIY kit for average person to purchase these units and install themselves and therefore the labour cost saving for the commercial marketing companies should make the present invention a commercial success.

Finally, the present invention operates only during high ambient conditions without any large water volume to evaporate on total waste i.e. no recirculation. The majority of the time the water presence remains with the sealed main water pipework and water spray pattern generates large water droplets which are 10~20 times larger than air borne legionella risk water mist operation therefore the health risk involved with a standing water reservoir as in the case of Munter or atomised water spray as in the case of Van Spall Associates systems are completely eliminated.

CLAIMS;

1) An adiabatic cooling module or apparatus consists of a metallic or non-metallic mesh water spray operation which is attached in front of a heat rejection surface using bracket, frame, box or clip-on configuration for the purpose of cooling the air stream for heat rejection equipment, direct evaporative air cooling for comfort cooling for commercial, domestic and industrial application.

2) An adiabatic cooling module or apparatus according to claim 1 wherein the heat exchanger surface is circular, rectangular or any other geometry in any aspect ratios to form a wired mesh panel which is placed within the air stream in order to provide adiabatic cooling affect.

3) An adiabatic cooling module or apparatus unit according to claim 1 wherein directly applied onto the heat rejection equipment or apparatus or alternatively applied in frame or box formats around the heat rejection equipment or apparatus.

4) An adiabatic cooling module or apparatus according to any foregoing claim 1 wherein an adiabatic cooling module or apparatus comprises a water flow / spray system which directly apply the main water supply onto wired mesh against the air stream.

5) An adiabatic cooling module or apparatus comprising a plurality of adiabatic cooling modules or apparatus units applied into a common heat rejection or direct evaporative air cooling systems according to any one of claims 1 to 4.

6) An adiabatic cooling module or apparatus in accordance with claim 5 wherein the units are connected in series and/or parallel.

7) An air conditioning, refrigeration, process cooling, food preparation, industrial process cooling, heat recovery system incorporation an adiabatic cooling module or apparatus according to any one of the claims 1 to 6.

8) An adiabatic cooling module or apparatus substantially as hereinbefore described with reference to Figure 4,5,6,7 and 8.

The Patent Office

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Application No: GB 0213054.0 8 **Examiner:** M C Monk
Claims searched: All **Date of search:** 4 December 2002

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A		GB 2365955 A	FU-CHIN LIU Absorptive material (202); water spray tubes (408); condenser coils (204).
A		GB 2318180 A	NUTEC ELECTRICAL ENGINEERING CO LTD Outer surface of the condenser may be coated with a water retaining film.
A		GB 2234339 A	KENLOWE LTD Capillary material (5,6)
A		GB 1504385	J MANN & SON LTD Consider whole document; annular porous member (16).
A		GB 901024	HAPPEL Consider whole document; water sprays (14,15); heat exchange elements (1,2).
A		GB 900949	HAPPEL Consider whole document.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{T}:

F4K, F4H, F4S

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

F24F, F25D, F28C, F28D

Application No: GB 0213054.0 9 **Examiner:** M C Monk
Claims searched: All **Date of search:** 4 December 2002

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO